DESIGN OF STEEL WALL STUDS WITH SERVICE HOLES

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ABSTRACT

Installing plumbing and electrical services into residential buildings requires holes to be located in wall studs. Holes can be pre punched during production or cut on site. Generally 2 or 3 holes up to around 30 mm in diameter are required in each stud. It is often convenient for these holes to be relatively close together.

Currently the Cold formed steel structures standard AS/NZS 4600:2005 (Standards Australia, 2005) gives design formulae for holes in channels up to 0.7 times the web depth, provided that the clear distance between holes is greater than or equal to 450 mm. Members containing holes that fall outside of these limits are required to be designed using testing or appropriate rational engineering analyses.

A minimum hole spacing of 450 mm is not always suitable for the placement of service holes in wall studs, however since service holes are usually much smaller than 0.7 times the web depth a closer spacing may not structurally compromise the wall stud.

This paper compares the structural performance of wall studs containing a range of hole sizes and spacings. Wall studs have been analysed and tested using a realistic combination of axial and bending loads. Suggested minimum spacing for holes up to 0.5 times the stud depth are presented.

INTRODUCTION

In developing a Handbook to assist engineers to design steel house frames, the National Association of Steel-framed Housing (NASH) wanted to include useful design information around the provision of service holes in wall studs. As most service holes are required to be around 22 – 32 mm diameter and most load bearing wall studs are around 70 – 90 mm deep, a maximum hole size of less than 0.5 times stud depth would cover most applications. Given that this is significantly smaller than the maximum hole size given in AS/NZS 4600 section 2.2.4 (Standards Australia, 2005) of 0.7 times the stud depth, it was considered that the hole spacing could be reduced without compromising the structural performance of the stud. To verify the performance of steel wall studs with a range of service hole configurations, BlueScope Steel Research carried out a series of structural tests where realistic axial and bending load combinations were applied. Finite element modelling of the test studs was also carried out. The test results were used to verify the accuracy of the model. This then allowed modelling to be extended to other studs and hole configurations.

STUDS CONSIDERED

The stud shapes considered in this paper are shown in Figure 1. A centreline bend radius of 2 mm was assumed for all sections.

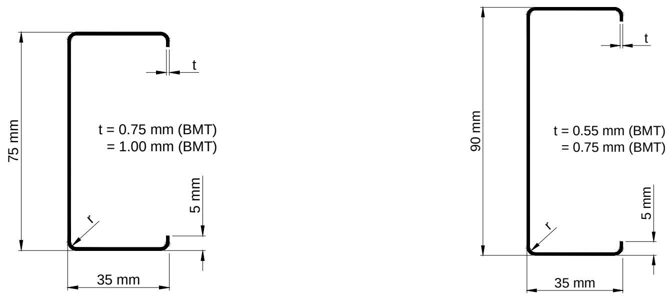

Figure 1. Wall Stud Sections

Grade G550 steel was used for all testing and analyses. The hole configurations considered are shown in Figure 2. The hole diameters and dimensions a through to k, where relevant, are given with the analysis and test results.

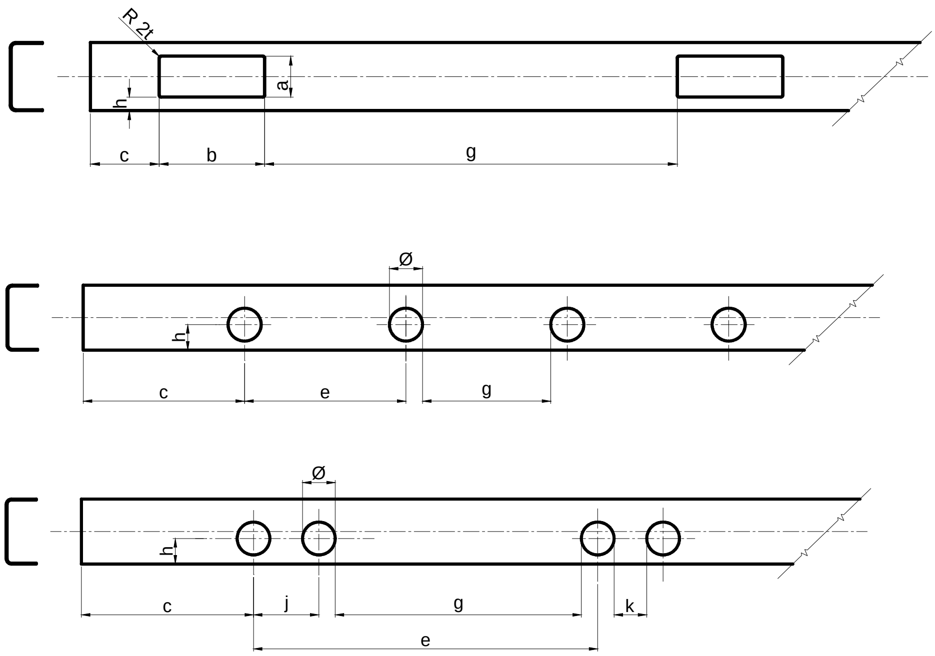

Figure 2. Hole configurations considered.

APPLIED LOADS

A combination of wind load and dead load (limit state strength loads) was applied to the studs using the following load combination from the NASH Standard Residential and Low-rise Steel Framing Part 1: Design Criteria (NASH, 2005)

$1.2\ G + (W_{uw} + W_{ur\ (down)})$

Dead Loads

Truss span = 10m, truss spacing = stud spacing = 600 mm
Concrete tiles = 0.54 kN/m^2 ,Ceiling = 0.1 kN/m^2 , Battens = 0.02 kN/m^2 + truss weight
Vertical reaction at stud due to dead load = 0.7 x 0.6 x 10/2 = 2.1 kN

Two wind load cases, N1 and N2, from AS 4055-2006 Wind loads for housing (Standards Australia, 2006), were considered. The applied load combinations are given in Table 1.

Table 1. Loads applied to wall studs

WIND LOAD N1	**WIND LOAD N3**
Axial load on stud due to wind = 0.49 kPa x 0.6m x 10m/2 = 1.47 kN 1.2 G + (W_{uw} + $W_{ur\ (down)}$) Axial load = 1.2 x 2.1 + 1.47 = 3.99 kN *Bending load on stud due to wind* = 0.69 kPa x 0.6m = 0.414 kN/m	*Axial load on stud due to wind* = 1.05 kPa x 0.6m x 10m/2 = 3.15 kN 1.2 G + (W_{uw} + $W_{ur\ (down)}$) Axial load = 1.2 x 2.1 + 3.15 = 5.67 kN *Bending load on stud due to wind* = 1.50 kPa x 0.6m = 0.9 kN/m

TESTING

Two tests were carried out on each stud configuration. The test results are shown in Tables 2 & 3. For each test a 2400 mm high x 1200 mm wide wall panel was constructed using 3 studs, a top and bottom plate, and a mid height noggin. 10 mm plasterboard was glued and screwed to the tension flange. Holes were located along the central stud only. Bending load was applied to the studs via 9 pneumatic cylinders. Cylinders were located at the mid point and 300 mm in from the top and bottom plates, to apply the uniformly distributed bending loads. Axial load was applied via 3 hydraulic cylinders located above each stud. The test configuration is shown in Figure 3. The axial and bending loads were increased together in increments of 0.1 x the limit state strength load. Bending deflection was measured near the mid height noggin on each stud. Typical failure mode is shown in Figure 4.

Figure 3. Test set up, 1.00 mm Lipped Stud with 38 mm round holes, 185 mm Centreline spacing.

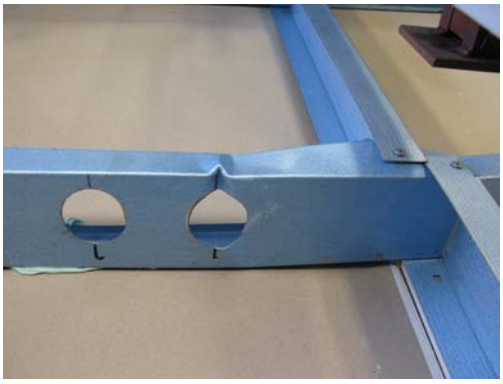

Figure 4. 90 x 0.55 mm Lipped Stud with pairs of 44 mm round holes, 400 mm Centreline Spacing – Failure.

Table 2. Test Results, Wind speed N3, 2400 mm high, 75 mm x 1.00mm lipped stud.

Stud Hole Configuration – as detailed in Figure 2.	**Load Factor at failure (Failure load/ design load) test 1, test 2**	**Mid height bending deflection at 1 x ultimate load (mm) test 1, test 2**	**Satisfies AS 4600 2.2.4 hole spacing requirement**
No Hole	1.9, 1.7	13.8, 13.4	Yes
Ø =44 mm, c = 96, e = 552 g = 508, h=37.5	1.6, 1.6	17.5, 16.4	Yes
Ø = 38 mm, c = 185, e = 185 g = 147, h= 29.5 (hole toward compression flange)	1.6, 1.6	15.0, 16.4	No
Ø = 38 mm, c = 162, e = 400 g = 286, h = 29.5, j = 76, k = 38	1.6, 1.5	15.9, 15.7	No

Table 3. Test Results, Wind speed N1, 2400 mm high, 90 mm x 0.55 lipped stud.

Stud Hole Configuration	**Load Factor at failure (Failure load/ design load) test 1, test 2**	**Mid height bending deflection at 1 x ultimate load (mm) test 1, test 2**	**Satisfies AS 4600 2.2.4 hole spacing requirement**
No Hole	1.5, 1.7	8.9, 8.1	Yes
Ø =60 mm, c = 120, e = 540 g = 480, h= 45	1.7,1.6	8.9, 8.1	Yes
Ø = 44 mm, c = 185, e = 185 g = 141, h= 36 (hole toward compression flange)	1.5, 1.6	10.9	No
Ø = 44 mm, c = 156, e = 400 g = 268, h= 36, j = 88, k = 44	1.5, 1.6	8.0, 10.0	No

FINTE ELEMENT ANALYSIS

Finite element analysis (FEA) was carried out using Strand 7 release 2.3.7. Stud sections were modelled using linear plate elements. Studs were restrained from in plane lateral and torsional movement at mid height and lateral movement at the ends, to simulate restraint from the noggin, top plate and bottom plate. The tension flange was also restrained laterally to simulate restraint from plasterboard. The bending load was applied through the compression flange at 3 points, simulating what was done in testing. Lateral restraint was applied at the loading points. The axial load was applied through the end of the stud. The axial and bending load combination was applied until the maximum supported load was reached. Non-linear analyses, including non-linear material properties were used. The material properties used were taken as the average of the values given in the BlueScope Steel datasheet for TRUECORE® G550 steel (BlueScope Steel, 2007) at each of the thicknesses considered. The material properties used are given in Table 4. The FEA results are given in Tables 5 & 6.

Table 4. Steel properties used for FEA.

Steel Thickness (mm)	**Yield Strength (MPa)**	**Tensile Strength (MPa)**	**Elongation (%)**
0.55	725	725	2.5
1.00	630	670	7

Table 5. FEA results, Wind speed N3, 2400 mm high, 75 mm x 1.00mm lipped stud, mid height noggins.

Stud Hole Configuration – as detailed in Figure 2.	**Load Factor at failure (Failure load/ design load)**	**Mid height bending deflection at 1 x ultimate load (mm)**	**Satisfies AS 4600 2.2.4 hole spacing requirement**
No Hole	1.8	14.7	Yes
Ø =44 mm, c = 96, e = 552 g = 508, h=37.5	1.7	14.7	Yes
Rectangular hole, a = 45, b = 115, c = 75 g = 450 (min), h = 15, R= 2	1.5	15.9	Yes
Ø = 38 mm, c = 185, e = 185 g = 147, h=37.5	1.7	14.7	No
Ø = 38 mm, c = 185, e = 185 g = 147, h= 29.5 (hole toward compression flange)	1.55	15.4	No
Ø = 38 mm, c = 162, e = 400 g = 286, h=37.5, j = 76, k = 38	1.7	14.8	No
Ø = 38 mm, c = 162, e = 400 g = 286, h = 29.5, j = 76, k = 38	1.6	15.5	No

Table 6. FEA results, Wind speed N1, 2400 mm high, 90 mm x 0.55 lipped stud, mid height noggins

Stud Hole Configuration – as detailed in Figure 2.	**Load Factor at failure (Failure load/ design load)**	**Mid height bending deflection at 1 x ultimate load (mm)**	**Satisfies AS 4600 2.2.4 hole spacing requirement**
No Hole	1.40	8.2	Yes
Ø =60 mm, c = 120, e = 540 g = 480, h= 45	1.3	8.9	Yes
Rectangular hole, a = 56, b = 115, c = 75 g = 450 (min), h = 17, R= 2	1.35	10.2	Yes
Ø = 44 mm, c = 185, e = 185 g = 141, h = 45	1.35	8.4	No
Ø = 44 mm, c = 185, e = 185 g = 141, h= 36 (hole toward compression flange)	1.30	9.3	No
Ø = 44 mm, c = 156, e = 400 g = 268, h= 45, j = 88, k = 44	1.35	8.6	No
Ø = 44 mm, c = 156, e = 400 g = 268, h= 36, j = 88, k = 44	1.35	9.6	No

NASH HANDBOOK GUIDELINES

Whilst AS/NZS 4600 (Standards Australia, 2005) is prohibitive for the provision of service holes in steel framed studs, the NASH Handbook – Design of Residential &

Low Rise Steel Framing (NASH, 2009) is more flexible. It currently allows for holes no larger than 50% of the depth of the member to be placed through the web within the following guidelines:

With hole centres within 10% of the centreline of the member

At a spacing or end distance of 4 times the hole diameter (for individual holes)

At a spacing or end distance of 8 times the hole diameter (for pairs of holes)

The testing and analysis results support these guidelines.

CONCLUSIONS

Both FEA and testing showed that structurally the hole sizes and spacings evaluated that currently do not comply performed similarly to those currently allowed for in AS/NZS 4600 sections 2 and 3 (Standards Australia, 2005).

This paper has provided evidence to support the development of more flexible requirements for spacing of service holes where the hole size is less than 0.7 times the web depth of the wall stud. The NASH Handbook – Design of Residential & Low Rise Steel Framing (NASH, 2009) currently allows for holes no larger than 50% of the depth of the member to be placed through the web within the following guidelines:

With hole centres within 10% of the centreline of the member

At a spacing or end distance of 4 times the hole diameter (for individual holes)

At a spacing or end distance of 8 times the hole diameter (for pairs of holes)

The findings presented in this paper support these guidelines.

REFERENCES

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